Chapter Y. Sediment Management

"The management of sediment in river basins and waterways has been an important issue for water managers throughout history – from the ancient Egyptians managing sediment on floodplains to provide their crops with nutrients, to today's challenges of siltation in large reservoirs. The changing nature of sediment issues, due to increasing human populations (and the resulting changes in land use and increased water use), the increasing prevalence of man-made structures such as dams, weirs and barrages and recognition of the important role of sediment in the transport and fate of contaminants within river systems has meant that water managers today face many complex technical and environmental challenges in relation to sediment management."

International Sediment Initiative, Technical Documents in Hydrology, 2011

In California sediment is valuable resource that properly managed results in multiple water benefits, environmental health, economic stability and coastal safety. Sediment definitions vary among the professional disciplines. Sediment, as reflected in this resource management strategy is composed of natural materials and used contextually as follows:

1. In Geology it is the solid fragmented material, such as silt, sand, gravel, chemical precipitates, and fossil fragments, transported and deposited by water, ice, or wind or that accumulates through chemical precipitation or secretion by organisms, and that forms layers on the Earth's surface. Sedimentary rocks consist of consolidated sediment.
2. For the US Environmental Protection Agency (EPA) and Army Corps of Engineers (USACE) it is material, such as sand, silt, or clay, suspended in or settled on the bottom of a water body.

Sediments can come from anywhere and be just about anything. Organic and inorganic material alike can become the bits of matter tiny enough to be picked up and carried along with a moving fluid. Organic sediments are mostly debris from trees, plants, grasses, and animals and fish and their waste products. Inorganic sediments are divided into two main groups, these being coarse-grained sediments and fine-grained sediments. Coarse-grained sediments are boulders, cobbles, gravel, and sand, while fine-grained sediments are silts and clays. Sediment deposits, like tree rings, can serve as a record of natural history.

A further important distinction of the sediments is whether they are "clean" sediments or contaminated sediments, as this greatly affects the manner in which they can be used as beneficial material or must be isolated from their surrounding environment. For this Resource Management Strategy the use of the term sediment will mean clean sediment, and if the sediment is contaminated the term contaminated sediment will be used.

Debris management is also associated with sediment management. Debris may contain sediment, but it is not entirely sediment. Likewise debris is not trash. Debris consists of fragmented materials of organic (trees, brush, and other vegetation) and inorganic (soil, rocks, boulders, and other sediment) origin that is primarily moved by flood waters. Debris basins are built in areas subject to debris flows to save lives and protect property. Trash consists of discarded man-made products (e.g. litter) that sometimes comingles with debris. Trash racks are typically placed on critical equipment, such as pump stations, to prevent mechanical failure caused by litter build-up during a flood." Debris management is critical in flood management and includes the post disaster removal of materials — both natural and man-made —

generated by a flood and extreme weather events. Debris in these situation can range from boathouses, to gravel bars, to zoo enclosures.

While debris management is linked, this chapter focuses on primarily on sediment management. Sediment management tools are essential for successful integrated water management as the presence or absence of sediment has significant impacts on water and its beneficial uses.

Sediment Management in California

Sediment, like fresh water, is limited in supply and is a valuable natural resource. Sediment management is critical for the entire watershed, beginning with the headwaters and continuing into the coastal shores and terminal lakes. But, from a human perspective, sediment has a dual nature—desirable in some locations and unwanted in others.

Sediment contributes to and is used for many positive purposes such as beach restoration, and renewal of wetlands and other coastal habitats. Sediment is also needed to renew stream habitat. Spawning gravels need replenishment, and fine sediment is needed to maintain, enhance, or restore good quality native riparian vegetation and wetlands. Flood deposits of fine sediment into floodplains are the source of much of California's richest farmland.   For centuries, sediment, particularly adjacent to hot springs has been considered to hold healing properties. Sediments can also be used for habitat restoration projects, beach nourishment, levee maintenance, and construction material.

The key to effective water-sediment management is to address excessive sediment in watersheds. Impacts of excessive sediment follow:

- Can cloud water, degrade wildlife habitat, form barriers to navigation, and reduce storage capacity in reservoirs for flood protection and water conservation.
- May increase turbidity and suspended sediment concentrations and negatively affect the ability of surface water to support recreation, drinking water, habitat, etc.
- Many affect sight-feeding predators in their ability to capture prey, clogs gills and filters of fish and aquatic invertebrates, covers and impairs fish spawning substrates, reduces survival of juvenile fish, reduces fishing success, and smothers bottom dwelling plants and animals. It may also physically alter streambed and lakebed habitat.
- Can reduce the hydraulic capacity of stream and flood channels, causing an increase in flood crests and flood damage. It can fill drainage channels, especially along roads, plug culverts and storm drainage systems, and increase the frequency and cost of maintenance.
- Can decrease the useful lifetime of a reservoir by reducing storage capacity. This loss in storage capacity affects the volume of stored water available for municipal supplies and the volume available for floodwater storage.
- In harbors and drainage systems results in higher maintenance costs and potential problems associated with disposal of removed sediment. The accumulation of excess sediment in ports, marinas along the coast, in working rivers and recreational lakes affects boating and shipping activity and can lead to demands for dredging to restore or increase depths.

Another key to effective water-sediment management is to address contaminated sediment in watersheds. Impacts of contaminated sediment follow:

- Contaminated sediment can bioaccumulate or biomagnify in the food chain and cause problems for aquatic plants, animals, and humans. Nutrients (such as nitrates, phosphorous, potassium) and toxic pollutants (contaminants such as trace metals and pesticides), when present, are associated with fine-grained sediment. These pollutants can impair water bodies. In some cases suspended sediment particles increase growth of bacteria which can concentrate these nutrients.
- Toxic pollutants from storm water may also be absorbed onto sediments. Concentrated pollutants can greatly impair water quality if they are remobilized back into the environment.

Management of watershed sediment location and movement can also have both positive and negative, as well as large economic and ecological consequences. For example, excess sediment in shipping channels may cost ports millions of dollars in delayed or limited ship access, while in other locations insufficient sediment deposits could result in the loss of valuable coastal wetlands, beaches, recreation and tourism worth billions of dollars.

Sediment processes are important components of the coastal and riverine systems integral to environmental and economic vitality. Management relies on knowledge about the context of the sediment system and forecasts about the long-range effects of management actions when making local project decisions. A major goal in sediment management is to stabilize the watershed for sediment production (meaning to try to mimic natural sediment production, not to eliminate it) and the various ecological and beneficial uses. Watershed stability is determined by performing geomorphic assessments of the waterways within that watershed. Then, for the sediment that is produced, make efforts to use this sediment most beneficially throughout the watershed.

Numerous factors, including geology, climate, development and population, and the location of littoral cells (littoral cells are defined as sediment within a coastal area that is circulated e.g. rip currents), affect sediment management issues. These vary significantly throughout the state. For that reason, sediment is best managed on a watershed-littoral cell basis, taking into consideration the sediment source and needs from the top of the watershed to the coast where it will ultimately end up. Regional sediment management recognizes sediment as a valuable resource and supports integrated approaches to achieve balanced and sustainable solutions for sediment related needs.

Management Framework

The California Water Boards also work to facilitate the transport of coarse-grained sediment to the coast and provide regulatory oversight for management of excessive watershed sediments. A stream that has excessive erosion, suspended sediments and/or sedimentation may be determined by the Water Boards to be unable to support its designated beneficial uses and may be listed as impaired under the Section 303(d) of the Federal Clean Water Act. The California Regional Water Quality Control Boards are working to reduce excessive sediment within streams when it occurs within their regions through the use of Total Maximum Daily Load requirements. The *National Water Quality Inventory: Report To Congress, 2004 Reporting Cycle (2005*), shows that sediment is a major water quality problem in the nation's streams.

TEXT BOX PLACE HOLDER (explains beneficial uses from the Water Board’s perspective)

Throughout California, partnerships have been formed to better manage sediments in a variety of ways. In San Francisco Bay, the USACE, the US EPA, the San Francisco Bay Water Board and the San Francisco

Bay Conservation and Development Commission (BCDC) formed a partnership to address the disposal and beneficial reuse of sediment dredged from the Bay. The “Long-Term Management Strategy for the Placement of Dredged Sediment in the San Francisco Bay Region (LTMS) reduces in-bay aquatic disposal of sediments in favor of beneficially reusing that sediment in habitat restoration projects, levee maintenance, agricultural enhancement and construction projects. LTMS emphasizes using sediment as a resource while simultaneously reducing impacts from aquatic disposal in the estuary. Through this program approximately 110 maintenance dredging projects, regulated by 8 state and federal agencies, are coordinated and managed under a common set of goals and policies. The LTMS policies and management practices also enable streamlining the permitting process, including coordinating programmatic consultations with the resource agencies, standardizing testing protocols and increasing predictability for permittees.

On a statewide basis, the California Coastal Sediment Management Workgroup (CSMW) was established by the U.S. Army Corps of Engineers (Corps) and the California Natural Resources Agency (Resources Agency) to develop regional approaches to restore coastal habitats such as beaches and wetlands that have been impacted by man-induced alterations to natural sediment transport and deposition through federal, state and local cooperative efforts. CSMW is comprised of many state, federal and local interests whose mission is to identify, study, and prioritize regional sediment management needs and opportunities along the California coast, and provide this information to resource managers and the general public. Other entities participating in CSMW in advisory role include California Marine Affairs and Navigation Conference (CMANC) and the Minerals Management Service is now called Bureau of Ocean Energy and Management.

The CSMW was formed in response to concerns about shore protection and beach nourishment needs in California. The consensus was that coastal sediment management is a key factor in developing strategies to conserve and restore California's coastal beaches and watersheds. The CSMW’s main objectives include: supporting beach nourishment projects; maintain stable watersheds; And maintain infrastructure capacity.

The CSMW oversees the development of the California Coastal Sediment Management Plan (SMP) (http://www.dbw.ca.gov/csmw/smp.aspx). The SMP will identify and prioritize Regional Sediment Management (RSM) needs and opportunities along the California coast, provide this information to resource managers and the general public, and streamline sediment management activities. Tools, documents and RSM strategies developed to date are available on the CSMW website (www.dbw.ca.gov/csmw).

Sediment Management and Flood Management

Sediment management is a key consideration in flood management. When a river breaks its banks and floods, it leaves behind layers of sediment. These gradually build up to create the floor of the flood plain. Floodplains generally contain unconsolidated sediments, often extending below the bed of the stream. These are accumulations of sand, gravel, silt, and/or clay, and are often important aquifers, the water drawn from them being pre-filtered compared to the water in the river.

Geologically ancient floodplains are often represented in the landscape by fluvial terraces. Fluvial processes are the movement of sediment, organic matter, and erosion that deposits on a river bed, and the land forms this creates. Fluvial terraces are old floodplains that remain relatively high above the present floodplain and indicate former courses of a floodplain or stream.

When floodplains are separated from the water source, through levees or other means, the natural process of equilibrium (which elevates the land through sediment deposits) is interrupted. This alters the historic flooding and sediment distribution patterns. In some cases sediments remain within the restrained channel, settling and reducing the capacity of the channel, increasing the likelihood of water overtopping or breaching, then flooding. In many cases this is avoided by dredging of the channel and then mechanically depositing the sediment in desirable locations.

Alluvial fans develop where streams, sediment or debris flows gather speed in narrow passages from the mountains then emerge into areas with greatly larger channel widths. A number of factors contribute to the severity including the degree of steep grades to flatter grades. Sediment, debris and water spill out in a fan shape settling out and depositing on its way. The channels on these fans range from shallow to very deep (several meters) with the speed of the flows moving boulders sometimes taller than a house. In California these conditions are found at mountain fronts, in intermountain basins, and at valley junctions. Alluvial Fans are found where sediment loads are high, for example, in arid and semiarid mountain environments, wet and mechanically weak mountains, and environments that are near glaciers.

Historic Context

A combination of both natural and man-made impacts to California water ways has led to today’s sediment management challenges and solutions. Historically and prior to California being a state, the management of sediment included the natural flow of sediment from the mountains into streams, meadows, rivers, lakes, and ocean. Native Americans understood the seasonal and climate impacts of water way flows and drought which impacted levels of sediment. The environment provided a wide variety of flora and fauna useful as food and tool manufacturing sources for Native peoples. (Theodratus, 2009). As Europeans encountered the territories now known as California, there was a need to dredge passages of interior water ways and to capture reliable water supply for their new settlements.

Many of California current sediment management issues also trace back to historic gold dredge activities beginning in the 1850’s. California’s Central Valley and Bay-Delta waterways experienced significant alteration caused by billions cubic yards of sediment and debris sent downstream from hydraulic mining operations. Court action stopped these activities. However, impacts from these activities continue today.

Ditches used for mining are still in use for agriculture today. The channel infilling that occurred in many of the gold bearing streams is still also in evidence today, and many streams such as the Feather and Yuba, a hundred and fifty years later, are still adjusting their watercourse.

Some early reservoirs in the State (Clementine, Englebright, Camp Far West) were initially built to capture the sediment. There are still millions of tons of mining debris remaining on the floodplain. The USGS has measured the amount of sediment entering the SF Bay from numerous tributary streams and determined the historic changes in sediment yield over the long term. Today, scientists have concluded that much of the hydraulic mining sediments have moved through the Delta and a potentially through much of San Francisco Bay; however, multiple institutions, laws and human settlement patterns created in this era remain.

Beyond the Delta and Central Valley, impacts from historic and current road building and land management practices continue to contribute to existing problems. Landslides are the major producer of sediment in the North Coastal and South Coastal areas. Road construction and poor timber harvesting techniques in the '50s and 60's resulted in an astronomical increase in sediment to rivers in the North Coast (almost wiping out the anadromous fishery), from which this part of the state is still recovering.

Additional system alterations also occurred as dams and channels were built for both water supply and flood protection. More and more structures changed what had been the natural hydrology, which then altered system stability for sediments. As a result, the normal function of waterways to produce sediment, move it through the watershed, with some settling occurring in low areas (areas now typically used for farming or urbanization) and ultimately depositing it at the shoreline, replenishing the coastline or terminal lakes, has also changed.

Land use has altered patterns of natural alluvial fans. For example, in Los Angeles (LA) County, much sediment is the result of the naturally erosive mountains. The San Gabriel Mountains are mostly undeveloped because they are within the Angeles National Forest. Other ranges (Santa Monica, Verdugos, Puente Hills) also have large areas of undeveloped land. The basins and valleys below these mountains are giant, relatively flat, alluvial plains. The depth of the sediment deposits indicates that a significant portion, and possibly the majority, of the sediment are from the adjacent mountains.

Many LA County residents/businesses settled in these flat alluvial plains. The original inhabitants, impacted by frequently fluctuating watercourse alignments, caused by high amounts of sediment deposition, wanted more stable river/stream alignments. Development in LA County, starting with agricultural development, started altering the alluvial areas' surface and groundwater hydrology, prompting the need to capture stormwater for use and recharge. This situation led to the construction of dams, debris basins, channels and spreading grounds in LA County. The facilities were constructed to serve agricultural and urban areas. Most of the agricultural areas later became urbanized. Farms and subdivisions essentially planted themselves in the very sediment disposal areas Mother Nature set up unaware that they are sitting on still active alluvial fans.

Management Approach

Understanding the cumulative impacts of all past, present, and proposed human activities in a watershed is important in predicting the impacts of sediment on surface waters. Sediment management in water bodies typically focuses on three issues:

1. Source management - addressing the type and source of sediment.
2. Transport of sediment - addressing the systems transporting sediment.
3. Deposition of sediment - addressing the location where sediment deposits.

Management actions are tailored depending on the location in which they occur and the whether the management concerns involve a non-built environment (rivers, streams, creeks and flood plains) or a built environment (water control structures, flood levees, dams).

Source Management

Source management occurs to prevent soil loss and adverse sediment flows from land use activities that may, without proper management, cause erosion and excessive sediment movement. Routine source management activities prevent or mitigate excessive sediment introduced into waterways due to recreational use, roads and trails, grazing, farming, forestry and construction. Excessive flows affecting erosion and sedimentation may also result from land based events such as extreme fire incidents, high water volumes, wind, and other factors.

Road construction and maintenance in or near streams can also be a source of sediment. Photo Y-2 is a picture of the Caltrans I-5 Antlers Bridge realignment project on Shasta Lake. The photo shows the dramatic erosion and sediment controls required for a massive cut and fill project that threatens surface waters (Central Valley Regional Water Quality Control Board 2011).

PLACEHOLDER Photo Y-2

[Any draft tables, figures, and boxes that accompany this text for the advisory committee draft are included at the end of the chapter.]

Another transportation related source is Off-highway vehicle (OHV) use. OHV is a popular form of recreation in California and state, federal, local agencies and private entities provide recreational areas for this purpose. These OHV recreation areas are required to implement a range of sediment management and storm water best management practices to protect water quality. Unfortunately unauthorized and unmanaged OHV areas can become erosion problems and discharge polluted storm water. With limited resources, maintaining and policing these areas can be a challenge.

Sedimentation can be a problem in the construction and operation of many mines. Increased potentials for erosion and sedimentation at mines are related to mine construction and facility location. Tailings dams, waste rock and spent ore storage piles, leach facilities, or other earthen structures are all potential sources of sedimentation to streams. Road construction, logging, and clearing of areas for buildings, mills, and process facilities can expose soils and increase the amount of surface runoff that reaches streams and other surface water bodies.

Agencies and Organizations Involved In Source Sediment Management

Many agencies and organizations contribute to sediment source management efforts as land managers, land use planners, advisors, and regulators, and through training, technical and financial assistance and promotion of good policy. An overview of some of those key entities and their activities follows in Table XX.

TYPE	AGENCY	ROLE	ACTIVITIES
Federal	• US Department of Agriculture (USDA) • Forest Service • Natural Resources Conservation Service • Bureau of Land Management • US Geological Survey	Land Managers, Advisors	Support California land management practices that incorporate erosion control and sediment management.

TYPE	AGENCY	ROLE	ACTIVITES
Federal	• US Fish and Wildlife Service	Regulators Advisors	Landscape Conservation Cooperatives
Tribal	• Tribal Governments	Land Managers, Planners	Plan and manage for sediment management considerations.
State	• CalFIRE • Board of Forestry and Fire Protection (BOF)	Land Managers Advisors Planners Regulators	Promotion of sediment management through best forest management practices. For over 20 years a group of advisors called the Monitoring Study Group (MSG) has, and continues, to: (1) develop a long-term program testing the effectiveness of California's Forest Practice Rules, and (2) provide guidance and oversight to the California Department of Forestry and Fire Protection (CAL FIRE) in implementing the program. The MSG has sponsored significant research on sediment management. This research informs CAL FIRE funded monitoring efforts designed to ascertain if forest practice rules, reducing unnatural sediment loads and protecting beneficial uses of water are being implemented and are effective.
State	• Department of Food and Agriculture • Department of Conservation • The University of California Extension Farm Advisors	Advisors Grant Administrators Training & technical Assistance	Provide significant leadership in source sediment management through the development of Best Management Practices (BMPs)
State	• Water Boards	Regulators Training & technical Assistance	Protect water quality through the issuance of regulations and permits which also serve as National Pollutant Discharge Elimination System (NPDES) permits for point source discharges subject to the Clean Water Act. Permits related to sediment control include stormwater permits for municipal stormwater systems, highways and other thoroughfares and construction activities. Permits require the implementation of best management practices (BMPs) at constructions sites, outreach and education to residents, and consideration of the principles of low impact development for

TYPE	AGENCY	ROLE	ACTIVITES
			redevelopment and new development sites. Non-point source (NPS) pollution can include sediment or pollutants carried by sediment. NPS pollution is divided into the following six categories: (1) agriculture; (2) forestry; (3) urban areas; (4) marinas and recreational boating; (5) hydromodification activities; and (6) wetlands, riparian areas, and vegetated treatment systems. The Water Boards administers grant funding to develop and implement management practices to address NPS pollution such as development and implementation of the California Rangeland Water Quality Management Plan (http://www.waterboards.ca.gov/publications_forms/publications/general/docs/ca_rangeland_wqmgmt_plan_july1995.pdf).
Regional	• Sierra Nevada Conservancy	Planning Financial Assistance Training & technical Assistance	Promotion of land use practices that support optimum source sediment management
Regional	• Tahoe Regional Planning Agency	Planning Regulation	Promotion of land use practices that support optimum source sediment management
Local	• Local governments, districts and planning commissions	Planning Regulation	Promotion of land use practices that support optimum source sediment management. Some local governments (city and county) support Low Impact Development (LID), including it as part of their planning and development ordinances. LID features design elements, including hydromodification, that address sedimentation at the source. Resources, including model regulations, are available to help municipalities interested in incorporating sediment source management into their planning portfolios (http://www.epa.gov/owow/NPS/lidnatl.pdf, http://www.epa.gov/region1/topics/water/lid.html, http://efc.muskie.usm.maine.edu/docs/lid_fact_sheet.pdf, and

TYPE	AGENCY	ROLE	ACTIVITES
			http://www.huduser.org/publications/pdf/practlowimpctdevel.pdf & http://www.mass.gov/envir/smart_growth_toolkit/bylaws/LID-Bylaw-reg.pdf).
Local	• Resource Conservation Districts	Advisors	Develop a land stewardship ethic that promotes long-term sustainability of the state's rich and diverse natural resource heritage.
NGO	• California and local Farm Bureaus • California Rangeland Trust	Advisors Advocates Training & technical Assistance	Information development and dissemination, policy advocacy
NGO	• California Association of Storm Water Quality Agencies (CASQA)	Advisors Advocacy Training & technical Assistance	Assists the Water Boards and municipalities throughout the state of California in implementing the National Pollutant Discharge Elimination System (NPDES) stormwater permits. One of the accomplishments of CASQA has been the development and dissemination of Best Management Practices (BMP) Handbooks. The BMPs help reduce unwanted delivery of sediment. The handbooks are designed to provide guidance to the stormwater community in California regarding BMPs for a number of activities affecting water quality and sediment management, including New Development and Redevelopment, Construction Activities, Industrial and Commercial Activities, and Municipal Activities (CASQA Web sites: http://www.casqa.org/ and http://www.cabmphandbooks.com).

Sediment Transport Management

Sediment like water, flows downstream and supports both shorelines and habitats at the end of the line. Rivers and streams carry sediment in their flows. There is a range of different particle sizes in the flow. It is common for material of different sizes to move through all areas of the flow for given stream conditions. The sediment can also be in a variety of vertical locations within the flow, depending on the balance between the upwards speed on the particle (drag and lift forces), and the settling speed of the particle.

PLACEHOLDER Box Y-2 Definitions

[Any draft tables, figures, and boxes that accompany this text for the advisory committee draft are included at the end of the chapter.]

Sediment transport management is the process of introducing or leveraging natural functions that create optimum sediment transport. This involves managing the speed and flow of the sediment conveyance and the natural or built structures to achieve a properly distributed balance of sediment types in the habitat. Properly managed transport of sediments will result in the optimal sediment deposition.

For example, sand bypass structures in flood control channels are starting to see some use. Such structures placed into flood channels allow the coarse-grained sediments to be diverted to a settling pond where they can be excavated and used for construction, while the fine-grained sediments are diverted to a wetland where they add to the size of the wetland. (More on this method can be seen at the web site http://www.ocwatersheds.com/Documents/wma/LaderaRanch_HNouri.pdf and http://www.ocwatersheds.com/Documents/wma/Integrated_Mgmt_of_Stormwater_Sediment_and_Pollutants_in_Ladera_Ranch.pdf.)

Sediment Deposition Management

The goal of sediment deposition management is to achieve optimum benefits from sediment deposits and mitigate negative impacts. As noted previously, properly distributed sediment has numerous beneficial outcomes such as:

- Fine grain sediments supporting existing habitat and for adapting to sea level rise.
- Gravel remaining in rivers and stream beds for habitat and river bed stability.
- Sand to sustain beaches both for recreation and habitat.
- Fine silts and clays introduce nutrient rich materials and nutrient cycling.
- Deposits creating buffers (particularly offshore) that reduce climate change and storm surge impacts. Coastal areas befitting from sediment can also include offshore mudbelts.

Deposition management also includes techniques to prevent and mitigate the negative aspects of excessive sediment including:

- Siltation impacting the capacity of floodways, reservoirs and water supply systems (including dams).
- Siltation creating unsafe shipping and transportation channels and impacting other commercial and recreational navigation
- Inundated wetlands

The US Army Corps of Engineers maintains the primary federal permitting and operational responsibility over waterway and navigational dredging, flood control, and the operation of many dams. The USEPA oversees USACE's implementation of its Clean Water Act and MPRSA responsibilities, as well as establishing water quality criteria and implementing certain TMDLs. Additionally, the Bureau of Reclamation maintains a significant federal role in maintenance, construction and even deconstruction of dams. The state Coastal Commission Department of Water Resources, the State Lands Commission, State Water Boards, and BCDC serve as state counter parts. Additional federal and state resource agencies are responsible for fisheries and recreation.

Dredging and Sediment Extraction

Dredging is an excavation activity or operation usually carried out at least partly underwater, in shallow water areas with the purpose of gathering up bottom sediments and disposing of them at a different location. This technique is often used to keep waterways navigable.

Other forms of sediment extraction can be completed by various methods including scraper, dragline, bulldozer, front-end loader, shovel and sluicing. Sluicing is a sediment removal method that employs water flow to remove smaller-particle sediment (i.e., sands and silts) to remove sediment accumulated in reservoirs. Sluicing is one of the two methods the Los Angeles County Flood Control District has used since the 1930s to remove sediment from its reservoirs.

Extraction methods are often used to maintain the capacity of flood and water supply infrastructure and mine sediment, sand and gravel for multiple purposes such as commercial construction, levee stabilization and environmental restoration. Determining how the extracted sediment will be managed involves a variety of factors including environmental acceptability, technical and economic feasibility.

Dredging is a critical sediment deposition management activity supporting commercial shipping, homeland security, fishing, recreation, and environmental restoration. Detailed descriptions of dredging equipment and dredging processes are available in Engineer Manual (EM) 1110-2-5025 (U.S. Army Corps of Engineers 1983), Houston (1970), and Turner (1984).

In San Francisco Bay alone, dredging facilitates a substantial maritime-related economy of over $7.5 billion annually. By necessity, maritime facilities are located around the margins of a bay system that averages less than 20 feet deep, while modern, deep-draft ships often draw 35 to 50 feet of water or more. In order to sustain this region's diverse navigation-related commercial and recreational activities extensive dredging — in the range of 2 million to 4 million cubic yards (mcy) per year — is necessary to maintain adequate navigation channels and berthing areas. Effective management of the large volumes of dredged material generated throughout the Estuary is both a substantial challenge, and an opportunity for beneficial reuse. Both are addressed by the **Long Term Management Strategy** for Dredging (**LTMS**). (source: http://www.bcdc.ca.gov/pdf/Dredging/EIS_EIR/chpt3.pdf) and the interagency Dredged Material Management Office. Navigational dredging in southern California is similarly managed to encourage beneficial reuse where ever possible, under the Los Angeles (LA) Basin Contaminated Sediment Management Strategy's master plan, and the interagency Dredged Materials Management Team.

There are some known issues related to dredging and other forms of sediment extraction such as:

- Dredging and sediment extraction can directly impact water quality, habitat quality and contaminant distribution. Operations may reduce water quality by introducing turbidity, suspended solids, and other variables that affect the properties of the water such as light transmittance, dissolved oxygen, nutrients, salinity, temperature, pH, and concentrations of trace metals and organic contaminants if they are present in the sediments (http://www.spn.usace.army.mil/ltms/chapter3.pdf).

- Depending on the location of the dredging, deepening navigation channels can increase saltwater intrusion (since saline water is heavier than freshwater), potentially impacting freshwater supplies and fisheries (e.g., deepening of the Sacramento and Stockton Deep Water Ship Channels in the Delta). Dredging can also increase saltwater intrusion into groundwater aquifers (e.g., the Merritt Sand/Posey formation aquifer in the Oakland Harbor area), with consequent degradation of groundwater quality in shallow aquifers

- Sediment removal operations also may reintroduce contamination into the water system by re-suspending pollutants. Metal and organic chemical contamination is widespread in urban shipping channels due to river run-off and municipal/ industrial discharges. Chemical reactions that occur during removal may also change the form of the contaminant. These chemical reactions are determined by complex interactions of environmental factors, and may either enhance or decrease bioavailability, particularly of metals. At the same time, dredging can aid in overall reduction of pollutants in a water body when contaminated sediments are removed from the system or sequestered in habitat restoration projects.

While these issues exist, many things have been done to address them. There are pre-dredging and real-time monitoring programs can have been developed to test the quality of sediments to be dredged, and there are alternative disposal sites that different quality sediments can be taken to. Time windows for when some dredging can occur have been established, so as to accommodate certain ecological cycles. Upland sediment disposal sites can be designed to mitigate for many contaminants, and extremely contaminated sites can be capped in-place underwater. Evaluation of dredged material for ocean disposal under the Marine Protection, Research, and Sanctuaries Act (MPRSA) relies largely on biological (bioassay) tests. The ocean testing manual, Evaluation of Dredged Material Proposed for Ocean Disposal - Testing Manual (Feb. 1991), commonly referred to as the Green Book, provides national guidance for determining the suitability of dredged material for ocean and near-coast disposal. Evaluation of dredged material for inland disposal under the Clean Water Act (CWA) relies on the use of physical, chemical, and/or biological tests to determine acceptability of material to be disposed. The inland testing manual, Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. - Testing Manual (Feb. 1998) provides national guidance on best available methods.

Beneficial reuse of dredged and extracted sediments can solve what can otherwise be a dilemma of how to dispose of it as a waste, by repurposing it in a variety of ways. It can be used to raise subsided lands to allow restoration, as an agricultural supplement, and to support levees. When this occurs the economics of disposal may be altered. in particular, the initial cost to the dredger for sediment removal and placement may be increased. For example, reusing the sediment may require different equipment, the transportation distance to the reuse site may be greater than to the traditional disposal site, and the amount of time needed to complete the dredging work may be extended In addition, sediment is a public trust asset and thus subject to state mineral extraction fees and other restrictions. Because public trust lands are held in trust for all citizens of California, they must be used to serve statewide, as opposed to purely local, public purposes.

Dam Removal

Dam removal is sometimes a result of, or creates a need for sediment management. As noted earlier, sediments trapped behind dams or in reservoirs may require periodic removal to maintain function and capacity. However this is sometimes extremely challenging due to the facility location and the lack of disposal or beneficial reuse opportunities in nearby locations. In recent years there has been increased interest in dam removals for sediment related reasons, such as the loss of capacity of the facility to hold water due to accumulated sediment. In other cases the reasons may be unrelated, such as a need to upgrade hydrogenation or improve a stream fishery. Analysis of dam removal proposals requires significant discussion of sediment deposition management. Management of sediments behind such dams has been an important element of negotiations related to dam decommissioning.

Regional Sediment Management

Regional Sediment Management (RSM) refers to a practice where sediment is managed over an entire region. Managing sediment to benefit a region potentially saves money, allows use of natural processes to solve engineering problems, and improves the environment. As a management method, RSM:

- Includes the entire environment, from the watershed to the sea.
- Accounts for the effect of human activities on sediment erosion as well as its transport in streams, lakes, bays, and oceans.
- Protects and enhances the nation's natural resources while balancing national security and economic needs.

RSM is an approach for managing projects involving sediment that incorporates many of the principles of integrated watershed resources management, applying them primarily in the context of coastal watersheds. While the initial emphasis of RSM was on sand in coastal systems, the concept has been extended to riverine systems and finer materials to more completely address sources and processes important to sediment management. It also supports many of the recommendations identified by interagency working groups on improving dredged material management. Examining RSM implementation through demonstration efforts can provide lessons not only on improved business practices, techniques and tools necessary for managing resources at regional scales, but also on roles and relationships important to integrated water resources management.

This is a growing concept nationwide and has economic benefits. The Army Corps of Engineers has a primer on Regional Sediment Management at: http://www.spur.org/files/u35/rsmprimer.pdf

More about RSM can be found in the American Society of Civil Engineers written Policy Statement 522, on Regional Sediment Management at: http://www.asce.org/Content.aspx?id=8638

Connections to Other Resource Management Strategies

Many other resource management strategies in the Water Plan Update 2013 share a connection with Sediment Management. More information on each of these resource management strategies can be found in their respective chapter under the Resource Management Strategies section of the CWP Update 2013.

- **Water Dependent Cultural Resource Management:** Sediment is used in traditional ceremonies and considered to contain healing, and in some cultures, spiritual properties. Mud structures are important to native peoples and for some; mud has ties to the creation story. (http://www.waterplan.water.ca.gov/docs/tws/TribalWaterStories_FullBooklet_07-13-10.pdf)
- **Land Use Planning and Management:** The way in which land is used—the type of land use, transportation, and level of use—has a direct relationship to sediment management. One of the most effective ways to reduce unnatural sediment loads is through land use planning that is fully abreast and reflective of applicable sediment and hydrology practices. This includes site design to reduce the introduction of unnatural loads of sediment into waterways.
- **Flood Management:** Floods have a major role in transporting and depositing unconsolidated sediment onto floodplains. Erosion and deposition help in determining the shape of the

floodplain, the depth and composition of soils, and the type and density of vegetation. Sediment transport dynamics can cause failure of adjacent levees through increased erosion or can reduce the flood-carrying capacity of natural channels through increased sedimentation. Sediment is also a major component of alluvial fan and debris-flow flooding.

- **Watershed Management:** Watersheds are an appropriate organizing unit for sediment management. Restoring, sustaining, and enhancing watershed functions are goals of sediment management in the context of IWM.
- **Stormwater (Urban) Runoff Management:** Urbanization creates impervious surfaces that reduce infiltration of stormwater and can alter flow pathways and the timing and extent of sediment introduction into the system. The impervious surfaces increase runoff volumes and velocities, resulting in stream bank erosion, and potential unnatural sediment distribution downstream. Watershed approaches to urban runoff management attempt to manage sediments to mitigate negative impacts and support beneficial uses in a manner that mimics the natural hydrologic cycle.
- **Agricultural Lands Stewardship:** Agricultural land stewardship directly links to management of erosion and soils protection. Proper management in both private and public land ownership, prevents disruptive development patterns, and supports sediment aware farming and ranching practices.
- **Forest Management:** Forestation practices can influence sediment transport from upland streams. Wildfires can reduce surface water infiltration, which can cause additional erosion and debris flooding.
- **Conveyance:** Depending on design, conveyance facilities can either trap, scour or in result in other unnatural distribution of sediments. Sediment overload can significantly reduce system capacity.
- **Surface Storage:** Similar to conveyance, sediments may be trapped behind infrastructure or otherwise unnaturally distributed. This results in a loss of system capacity.
- **Outreach and Education:** Outreach is needed to regularly educate the public on sediment management concerns. Outreach is also needed to educate the public on the natural, beneficial functions of sediment.
- **Ecosystem Restoration:** Native riparian and aquatic animal and plant communities of California are dependent on effective sediment management. These ecosystems are dynamic in nature and highly productive biological communities given their proximity to water and the presence of fertile soils and nutrients. Many opportunities for improvement in both sediment management and ecosystem restoration occupy the same spatial footprint and are affected by the same physical processes that distribute water and sediment in rivers and across floodplains. Sediment management projects that result in protected and restored ecosystems will likely create increased effectiveness, sustainability, and public support.
- **Pollution Prevention:** Well designed pollution prevention efforts improve water quality by filtering impurities and nutrients, processing organic wastes, controlling erosion and sedimentation of streams.
- **Water-Dependent Recreation:** Water and land based recreational activities can contribute to unnatural erosion and sediment production. Conversely, high sediment loads can negatively impact recreation, particularly boating, fishing and swimming.

Potential Benefits of Sediment Management

The ultimate benefits of sediment management relate to preventing the negative results of too little or too much sediment and repurposing sediment for beneficial uses. As noted above, benefits associated with reducing impacts to navigation and commerce alone may achieve cost savings by millions of dollars. A similar statement can be made about the management of sediment that accumulates at reservoirs and debris basins and is prevented from flooding communities downstream.

Source Sediment Management

An average of 1.3 billion tons of soil per year are lost from agricultural lands in the U.S. alone due to erosion (http://landresources.montana.edu/SWM/PDF/Final_proof_SW3.pdf). Considering soil formation rates are estimated to be only 10–25% of these erosion rates (Jenny, 1980), loss and movement of soil by erosion is a major challenge for today's farmers and land managers. Soil erosion over decades can have detrimental effects on productivity and soil quality because the majority of soil nutrients and soil organic matter (SOM) are stored in the topsoil, the soil layer most affected by erosion. For these reasons and more, sediment management for soil sustainability has numerous multiple benefits far exceeding the scope of the Water Plan.

In the case of urban land management, use of low impact development and other sediment management practices can reduce negative impacts of storm water run-off, by maintaining the natural production of sediment and improving permeability of drainage areas. Land use goals for sediment may also improve flood management. By improving the flood system hydrology, sediment management results in improved safety, and environmental and economic outcomes.

Coastal Sediment Management

In the coastal waterways sediment can serve to furnish material needed to replenish the beaches and marshes along the coastal areas. If the sediment is removed from navigation channels or harbors, the extracted material can be used for beach or marsh nourishment, construction purposes such as highway sub-base material and flood control levees.

Widening the shoreline, either via beach nourishment or marsh restoration, improves storm surge and flooding protection. The dollar value of this improved protection is nearly incalculable, not just for those that own coastal structures, but for the stunning number of infrastructure improvements that support the state including power generation, major transportation assets, water systems, etc., and the dollar value of the recreation and tourism industries to the state's economy.

Fisheries

In terms of water management, natural amounts of coarse-grained sediment (sand and gravel) in the stream and river system has many beneficial uses. In the inland waterways it can serve as a substrate for fish spawning areas. Enhancing the sustainability of the fishery benefits not only the State's fishing industry but is also a water supply benefit as a declining fishery may lead to reductions of water exports, or use of some water rights.

Beneficial Uses for Extracted Sediment

Extracted sediment is a manageable, valuable soil resource, with beneficial uses of such importance that they should be incorporated into project plans and goals at the project's inception to the maximum extent possible. For example, extracted sediment can benefit:

- Habitat restoration/enhancement (wetland, source, island, and aquatic sites including use by fish, wildlife, and waterfowl and other birds)
- Beach nourishment
- Aquaculture
- Parks and recreation (commercial and noncommercial)
- Agriculture, forestry, and horticulture
- Strip mine reclamation and landfill cover for solid waste management
- Shoreline stabilization and erosion control (fills, artificial reefs, submerged berms, etc)
- Construction and industrial use (including port development, airports, urban, and residential)
- Material transfer (for fill, dikes, levees, parking lots, and roads.
- Multiple purposes (i.e., combinations of the above)

Detailed discussion about various beneficial uses for extracted material given at http://water.epa.gov/type/oceb/ndt/beneficial_use.cfm and other related sources.

System Capacity and Materials Use

There are multiple benefits of managing the sediment that accumulates at reservoirs and debris basins. If sediment that accumulates in reservoirs is not removed, storage capacity for water is reduced. As an example, for those flood control reservoirs which have a water conservation purpose (and most of them do), water captured in the reservoirs maybe used to recharge local groundwater aquifers. Sediment that is sluiced from a reservoir may impact infiltration rates at spreading grounds used to replenish groundwater aquifers. If sediment is not removed from reservoirs and debris basins, the ability to provide flood risk management and water supply benefits is diminished.

Special Situations

The battle to retain Lake Tahoe as a pristine visual jewel is an unusual sediment case study. Here the sediment concern is very fine sediment (that less than 20 microns) that affects the clarity (and people's aesthetic enjoyment) of Lake Tahoe. In this case, the problem may be unique and so the extensive costs of Basin-wide improvements would not translate to other situations. Even so, many best practices for sediment management have been pioneered in the Basin and these can translate to other programs. Additionally the benefits of the investment have been equally evaluated and considered of national interest.

Potential Costs of Sediment Management

Many, many agencies and organizations engage in sediment manage activities. The cost of implementing Sediment Management to achieve Water Benefits varies widely depending on the sector and purpose of the management. When looking at the overall costs of sediment management, managers should consider and quantify the beneficial uses of the sediment and the ecosystem services, flood protection, storm surge protection and water quality improvements associated with the beneficial as a balancing measure in comparison to the upfront financial investments. While the financial investment is often a one-time cost, the benefits are regularly long term, such as creating a wetland that provides habitat and water quality improvements in perpetuity.

A few sample investments in sediment management follow:

Natural Resources Conservation Service (NRCS) - From 2007 to 2012 the NRCS obligated over 91 million dollars in California for conservation practices to address soil erosion and sedimentation on agricultural land. These practices are recommended to reduce erosion, prevent the transport of sediment, or trap sediment before it leaves the farm or field.

Forest Service - Overall watershed restoration project costs on National Forests are close to $2,000/acre, and most of these projects have benefits in terms of reducing erosion and sediment transport. Meadow restoration using the pond and plug approach is about $1,000/acre. Road decommissioning costs about $16/cubic yard of sediment (reduction in potential erosion)

LA County Flood Control District (LAFCD)- Based on the alternatives included in the LACFCD's Draft Sediment Management Strategic Plan (April 2012), the cost to manage the Strategic Plan's 67.5-MCY planning quantity could be as much as $1.2 Billion over the 20-year planning period (2012 to 2032).

U.S. Bureau of Reclamation (USBR) and U.S. Bureau of Land Management (BLM) - Gravels are added to northern California rivers to aid in the anadromous salmon run each year. The amount of gravels added depends on the budget allocated each year. Such gravel additions are occurring in the upper Sacramento River area (i.e Clear Creek), and in other rivers such as the American River, Yuba River, and Stanislaus River. The costs per ton of gravel added depends upon such factors as the method of placement, tonnage of gravel placed, and how the gravel is placed (dump trucks dumping directly into river, lateral berms laid alongside the stream bed at low water, or sluicing a mix of water and gravel directly into the river). Typical tonnages added may vary from 5,000 tons to 10,000 tons and more per application. Also, the U.S. National Fisheries Service specifies the amount of cleaning (washing) that has to be done to the gravels prior to application, and the grain size distribution of the gravels, and this adds to the cost.

Major Issues Facing Sediment Management

The issues facing implementation of Sediment Management are similar to those experienced by related Resource Management strategies, including the following:

- The need to balance environmental impacts, social impacts, feasibility, and cost.
- Availability and affordability of land
- Different stakeholders have different needs and a different understanding of the need to manage sediment
- Local managers implementing site-specific solutions without consideration of the regional backdrop and how regional processes affect the local conditions
- Stakeholders and regulators lack a complete understanding of the different natural regional sediment regimes and attempt to address issues on a statewide basis.
- Urbanization and other structural limitations may preclude introduction of truly natural regimes.

- Conflicting Federal, State and local regulations and agency missions, and regulators' unwillingness to compromise to navigate these conflicts for the good of a region.
- Significant nimbyism.
- Budget constraints.

Issues facing the three management approaches follow.

Sediment Source Management

Lack of Techniques for Coarse-Grained Sediments Management

Additional efforts are needed to support availability of the coarse grained fraction of the natural supply of sediments (sand and gravel), but not the fine-grained sediments (silts and clays) from the watershed to enter the streams and rivers so they can replenish these sediments in fish spawning areas, and also move toward the ocean thereby replenishing the sand along the coastal beaches. Research is needed in this area, as not many techniques now exist for coarse-sediment bypassing in inland watersheds. One project in the Bay Area, Flood Control 2.0, was recently funded by the EPA's Water Quality Improvement grant program is examining this very question. The project will be underway for the next four years and intends to examine the coarse grain load in Bay Area Flood channels, characterize the channel configurations and constraints and then identify ways to move coarse grain sediment through the channels to the shoreline or to develop bypass areas where the sediment is diverted into habitat areas where it is much needed.

In particular, efforts must be made to keep coarse-grained sediments available and clean in fish spawning rivers and streams. Erosion in unstable watersheds brings fine-grained sediments into the channels which may settle and cover the coarse-grained sediments needed for spawning, thus elimination them from use in the spawning process. (A web site describing these needs is at: http://www.joewheaton.org/Home/research/projects-1/past-projects/spawning-habitat-integrated-rehabilitation-approach-shira-.)

Barriers to Supplying Coarse-Grained Sediments to the Coastal Beaches

Many of the beaches along the coastline are receding because their natural supply of coarse-grained sediments from inland rivers has been stopped by dams, covering of areas by impermeable pavements, stormwater controls, changes to the ground surface, and other land use practices. This situation is anticipated to worsen and accelerate with sea level rise. As noted above, the CSMW is working toward this effort but challenges remain as agencies aim to work collaboratively, identify the necessary funding and overcome the traditional jurisdictional conflicts that create misalignment of policy and regulation.

Along the coast, beach nourishment has usually been undertaken by combining the USACE's or other dredgers' maintenance dredging of sandy areas and pumping it or placing adjacent to or directly on the shoreline for distribution either via wave action or by mechanical means. This practice has been well received, however funding remains tight. Even with these success, a challenge to beach replenishment occurs when material must be transported over land through beach neighborhoods in order to get to the beaches. In some California locations, sandy beaches (primarily used for recreation) are manmade and require continual replenishment, maintenance and support.

Cost Allocation

The issue of whose budget pays is a major barrier to reuse of any kind. Often reuse is not only environmentally beneficial, but also presents the optimal use of the overall society's funds. But even then, if the dredging budget will not pay for any increase in placement costs compared to "disposal", and when the reuse site will not share some of the costs for receiving otherwise free material from the dredging project, the reuse does not occur. An USACE publication addresses this very problem, available at http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/upload/2009_02_27_oceans_ndt_publications_2007_fed_standard.pdf

Lack of broader policy discussion of this general issue is a lost opportunity to recommend to CA that it do a number of things, for example encourage Congressional action to revise how the Harbor Maintenance Trust Fund is distributed and continued support or even increased funding to entities such as the Coastal Conservancy to cost-share with USACE dredging projects, etc.

Controlling Excessive Sediment from Entering Eutrophic Waterways

Eutrophic waterways typically have a lot of minerals and organic nutrients that benefit plants and algae. They often appear dark and have poor water quality. This occurs when certain nutrients such as phosphorus are absorbed on fine-grained sediments and carried into the waterways and lakes. These nutrients can cause algae blooms in a lake which create a lack of oxygen resulting in fish kills. The sediments themselves result in a reduction in light clarity in lakes, thereby harming the food chain and also reducing the aesthetic quality of the lake. Controlling these conditions is challenging and a failure to do so, is especially harmful at Lake Tahoe.

Implementation of Regional Sediment Management

Practical implementation of RSM, faces obstacles. RSM requires a long-term (multi-year) and watershed view and planning; yet it may be difficult for stakeholders and regulatory agencies to adopt long-term views and without the necessary scale. Federal, State and local regulations are sometimes in conflict with each other. Successful RSM requires compromise from everyone. Regulators often do not offer compromise due to statutory requirements, non-recognition of others' jurisdiction and fear of exposure to 3rd party lawsuits. Additional challenges RSM faces are: finding re-use projects/activities that occur at the same time sediment needs to be removed; long distances between potential users and the sediment source; and opposition from inhabitants/stakeholders.

Limited Options Due to Other System Requirements

In some cases, the optimum sediment management approach may be precluded due to other system requirements or previously implemented decisions and goals.

As an example, a major shift in land use and population patterns may not be feasible. On a specific project level, large amounts of sediment already accumulated behind reservoirs prohibit the immediate implementation of a different approach to sediment management (e.g. a reservoir may need cleanout out to its original condition before a sediment flow-through approach can be implemented).

Sediment Transport Management

Lack of Monitoring on Stable (Reference) Sediment Conditions in Watersheds

There is benefit in achieving and maintaining watersheds in a stable condition as it relates to the generation and transport of sediments from the land surface to the surface streams. To do so requires understanding (assisted by geomorphic assessments on channels) and monitoring to determine when watersheds are stable or unstable. Management without these tools cause stream channels to degrade in their geomorphic form and not support the native aquatic biological habitat, and affect domestic water supplies (filtration). Unstable sediment conditions may also result in disruption of flood control structures.

Achieving Broad Support for Establishing and Implementing Biological Objectives in Streams

Excessive sediment in streams, or lack of natural sediment loads can be detrimental to the aquatic life. Biological objectives for suspended sediment are being established because of their effect upon the fishery and algae. Efforts are being made to control the deposition and erosion of sediments from the stream channel bottoms because of their effects on aquatic invertebrates. Watershed efforts are needed to control sediment generation and runoff to the streams to meet biological objectives. The State Water Resources Control Board is establishing biological objectives, which will include those for suspended sediment as well as deposited sediments. (A web site containing this information is available at: http://www.waterboards.ca.gov/plans_policies/biological_objective.shtml.) Achieving broad support for establishing and implementing biological objectives is sometimes met with resistance.

Sediment Deposition Management

Securing Disposal/Placement Locations

Finding disposal locations has become increasingly difficult and expensive, due to development of nearby land, regulatory constraints/ requirements or opposition from those adjacent or along the haul routes to the deposition sites.

Another challenge to disposing of/reusing dredged sediment on dry land is de-watering the sediment. Due to the high content of water if the project is hydraulically dredged, the de-watering areas need to be quite large, and a region may not have sufficient space available.

When dredged material is placed at an upland dewatering or stockpile site, often the beneficial uses that can later be made of it are not known until a particular reuse is proposed and the Regional Water Quality Control Boards analyze the sediment quality data collected during dredging. This is because sediment that may be chemically suitable (“clean” enough) for one kind of reuse may not be suitable for other kinds of reuse. Often this results in delays for projects wanting to reuse the sediment, and can also tie up the emptying and use of the storage sites for future projects.

Handling Contaminated Sediments

Management of contaminated sediments may be challenging. There are limited resources for cleaning of the sediments and disposal or containment of contaminated ones. The USACE has a National Center of Expertise for handing contaminated sediments, at: http://el.erdc.usace.army.mil/dots/ccs/ccs.html.

Contaminated Sediment Management

The potential for contamination is a consideration whenever dealing with sediments, whether in upper watersheds or in ports and harbors. When a project or a watershed has to contend with contaminated sediment, special considerations need to be applied. Even contaminated sediment can often be reused, but and a more limited set of potential uses for that sediment may be available.

Reuse Challenges

Additional challenges to using sediment for beneficial uses are: finding beneficial use projects that coincide with the timing of sediment removal; long distances between the sediment removal site and the beneficial use site; offloading equipment needs, encountering regulatory obstacles; and encountering steep disposal fees at the beneficial use site.

Regulatory Requirements

Regulatory and management frameworks involving sediment typically are designed to support specific uses. As a result they involve multiple agencies and jurisdictions not necessarily accommodating of the complexities of managing all the aspects of sediment sources, transport and deposition. As a result, sediment related projects and/or multiple benefit projects may not be feasible due to timing, costs and conflicts related to the desired deposition of the sediment. Regionally, the LTMS program previously described provides a cooperative framework for testing, permitting and beneficial reuse projects. The LA-CSTF is a similar interagency regulatory group. Significant effort and energy is required to maintain such cooperative and collaborative efforts when dealing with dredging and beneficial reuse projects.

Data Availability

A number of issues related to integrated management and better planning and coordination could be improved with better data availability. For example:

- Better planning and decision making could occur with coordinated mapping efforts to allow agencies to better consider upstream and downstream impacts prior to decision making.
- On-going monitoring would allow better adaptive management and an evaluation of management methods being used.
- Improved forecasting and modeling would support long term and strategic planning.
- Development of sand and sediment budgets would assist agencies in planning and reduce regulatory conflicts.

Sediment and Climate Change

Climate change is already occurring and is projected to continue to alter temperature and hydrology patterns in the State. Climate change studies project an increased frequency of extreme weather; higher temperatures, larger and more frequent wild fires, longer droughts and more precipitation falling in the form of rain than snow. These changes will bring shifts in vegetative species, heighten soil exposure and cause flooding to already vulnerable lands, adding a heavy mix of sediment and debris to storm waters. Coupled with sea level rise, which increases beach erosion and coastal flooding, climate change will amplify the already difficult task of sediment management.

Adaptation

Adaptation will necessitate projecting where excessive sediments will source and accumulate, and building controls that will allow for effective management of those sediments. With climate change expected to bring wetter winter and drier summers, erosion will become an even greater threat to California lands and sediment management. Two adaptation strategies would provide benefit in light of climate change. Floodplain restoration, which allows for natural deposits of beneficial sediment, would serve dual purposes of managing sediment and replenishing soil. Excess, clean sediment can be beneficially used on eroding beaches and agricultural lands, mimicking natural processes.

Warmer temperatures and higher levels of CO_2 may, in some cases, lead to increased vegetation. Vegetation can minimize run-off and lessen erosion; preventing sediments from entering waterways. Effective management of landscapes including the planting of heat and drought tolerant native vegetation around waterways will minimize sediment loads.

Mitigation

Sediment management is a continuous process that can result in high green house gas (GHG) emissions. Dredging and channel clearing is necessary to ensure adequate capacity for flood protection, water supply and navigation, but is a constant source of GHG emissions from fossil-fuel powered equipment. Ports in some areas have begun to convert to shore-side electric power that could be sourced to renewable energy as more dredges gain the capabilities of using electric power. But this will take a major industry effort to convert to a different system. Additional analysis should be undertaken to fully recognize the value of beneficially reusing dredged sediment in habitat projects, and the carbon sequestration capabilities of marshes and riparian habitats. Once these analyses are complete, projects can evaluation whether the green house gases created by dredging are fully offset by the beneficial use project.

Recommendations to Facilitate Sediment Management

Policy and Regulatory Reconciliation

1. The State and USACE should convene a stakeholder working group that includes flood protection and water supply entities to recommend methods to overcome sediment management regulatory conflict and encourage long-term thinking, including the issuance of permits that match the time horizon for any established sediment management plan. Other topics for consideration by this group include developing ideas for protecting agencies from 3rd party litigation on sediment management plans that required compromise and setting permit processing deadlines.
2. The stakeholder group should also evaluate needs for outreach and education on sediment management and offer recommendations for next steps to address that need.
3. The USACE, Resources and California Environmental Protection Agency, Department of Finance, the Governor’s Office of Planning and Research and the California Water Commission should convene a task force or stakeholder working group to recommend methods to recommend methods for sediment management cost allocation. Often reuse is not only environmentally beneficial, but also presents the optimal use of the overall society’s funds.
4. Creation of new requirements for sediment management may increase costs and/or the amount of time needed to obtain permits. All new sediment recommendations should be strongly evaluated to determine to what extent they could inhibit important water-flood projects and

activities. If impacts may occur, some form of mitigation for these effects should be included in implementation of the recommendation.

Sediment Source Management

1. The Governor's Office of Planning and Research should develop model General Plan Policies that support optimum sediment source management.
2. Federal, Tribal, State, Regional and Local agencies and stakeholders should support and participate in Regional Sediment Management—For those sediments which must be dredged to keep the waterways and other facilitaties open to navigation or to support flood control efforts, support those efforts to use that sediment beneficially within the region. One possible use of the sediment is for levee construction that can direct the floodwater to the most desirable location.
3. The State Lands Commission and other responsible agencies should scrutinize in-stream and beach Sediment Mining Permits - On a case-by-case basis, evaluate impacts of sediment-mining permits which allow the removal of coarse-grained material directly from stream beds or from coastal beaches—While such permits may be satisfactory in some instances, in other instances such permits reduce the sediment needed for fish spawning beds and for beach replenishment along the coast.
4. The State should implement the requirements recommended by the California Association of Storm Water Quality Agencies (CASQA) for stormwater discharge control programs which are (1) technically and economically feasible, (2) provide significant environmental benefits and protect the water resources, (3) promote the advancement of stormwater management technology, and (4) effect compliance with State and Federal laws, regulations and policies. Reducing or controlling stormwater discharges keeps watershed and industrial pollutants from running into the waterways, thereby improving water quality.

Sediment Transport Management

5. The State should support research and design of fine-grained and coarse-grained sediment bypass structures—This will allow the coarse-grained sediment to be separated and either enter the streams and serve its many beneficial uses there, such as for fish spawning grounds and the restoration of coastal beaches, or be trapped in detention ponds where it can be excavated and beneficially used. The fine-grained sediment will be separated and can be used for wetland establishment or other uses. The separation and removal of fine-grained sediment with their attached nutrients can help improve the water quality in lakes having excessive eutrophication.
6. The Water Boards should work with stakeholders to secure broader support of sediment "Total Maximum Daily Load" (TMDLs) efforts and promote development of stakeholder based implementation plans to address excessive sediment problems.
7. The State should support the use of watershed mathematical models, when the occasion demands, which can track sediment from source to transport in the streams. Such models (such as SWAT, HEC-HMS, and HSPF) need adequate calibration and validation, but once done these models can help to manage the sediments throughout the watershed. The watershed model can also predict the concentrations of other water quality substances in the water.
8. The Resources and CA Environmental Agencies should implement an integrated approach to, as much as possible, achieve the maintenance of stable watersheds—A stable watershed is one where sediment yield mimics the natural sediment production that would occur in the absence of anthropogenic conditions. [Note: there are watersheds with geology that is naturally erosive.

So, these watersheds can produce flows with heavy sedimentation and still be stable.] If the watershed is not stable, assist in efforts to make it so.

Sediment Deposition Management

1. The State in cooperation with the local sediment management agencies should determine the Sediment Yields of Watersheds_when downstream sediment problems are becoming an issue. These yields (such as in tons/square mile/year) can be determined at monitoring sites, which have matching pairs of suspended sediment concentrations and instantaneous flow rate measurements. Knowing the sediment yields will help in managing extraction and dredging budgets for the navigation channels and other non-navigation facilities.
2. The Water Boards in cooperation with the local sediment management agencies should develop regionally based sediment screening criteria so that agencies could know sooner what the use of the dredged material could be and plan accordingly. (One of the Boards does have this screening criteria developed.) Establish potential uses of dredged material, depending upon its quality in advance. The upland sites receiving dredged material can then be emptied sooner and be available for additional dredged material. This will assist in maintaining the shipping channel in operational condition.
3. The State should prepare Sand Budgets for each watershed when downstream sand availability issues are occurring. Comparisons of these sand budgets over time for each watershed will tell of the effect of source Best Management Practices in affecting sand transport, will be of use in determining how well sand is moving toward the coastal beaches, will allow comparison of sand generation in the watershed to that removed by in-stream sand removal permits, and will tell which watersheds are the best in generating sand.
4. All affected jurisdictions should work with or through the CSMW, who are preparing plans for individual littoral cells along the coast.
5. The State should support and incent expanding successful interagency models to cover dredging projects throughout the state. Identifying beneficial reuse opportunities that support RSM goals should be a key objective of the state's involvement.
6. The State should develop a funding source to encourage and support beneficial reuse projects, specifically those that enhance, restore or support habitat, including beach nourishment and wetland restoration projects. State funding can be partnered with federal and private funds to support these efforts.
7. State may also consider ways to encourage beneficial reuse of sediment without State funding, specific ideas include providing a tax credit or mitigation credit when sediment is beneficially reused rather than treated as a waste product.
8. For sediment removal projects from facilities that capture sediment from undeveloped watersheds (e.g. some dams and debris basins), State agencies should allow pre-testing to facilitate deposition of sediment at solid waste landfills, inert landfills, and other potential deposition sites, which otherwise may require testing and affect beneficial use of sediment, especially in emergency situations.

Data Acquisition and Management

9. The Federal and State government should support, as appropriate, geomorphic assessments of streams to determine if a watershed is stable as regards sediment production. Guidelines should

be developed to identify when such studies are appropriate to prevent inappropriately large-scale expensive studies on small projects and prevent undue delays in processing permits.

10. The Federal and State government should support sediment and flow monitoring programs of others if needed to determine the sediment yields from a watershed and sediment budgets for downstream areas. They should also establish monitoring protocols that produce scientifically-defendable data of comparable quality throughout the State. Such monitoring will add to the water quality data base of the waterway.
11. The Federal and State government should support modeling and monitoring for sediment dynamics in estuarine and nearshore (littoral cell) environments when understanding estuarine and nearshore sediment transport issues is key to adaptive management, infrastructure protection, and habitat restoration.
12. The State should establish a Sediment Data Base and cooperate with others who may be obtaining sediment data in a watershed so that a common data base is used that is accessible to all users.
13. All responsible agencies should utilize a common GIS Mapping framework and use GIS to overlay maps relating sources of excessive sediment production in watersheds with areas having sediment problems in the stream in those watersheds.

NOTE - REVIEWERS MAY IGNOR THIS SECTION, IT LISTS PLACE HOLDER TEXT AND REFERENCES.

PLACEHOLDER Box Y-3 Case Study: Sediment Management Related to Recreational Use

[Any draft tables, figures, and boxes that accompany this text for the advisory committee draft are included at the end of the chapter.]

PLACEHOLDER Box Y-4 Case Study: Los Angeles County Flood Control District — Impacts of the 2009 Station Fire

[Any draft tables, figures, and boxes that accompany this text for the advisory committee draft are included at the end of the chapter.]

PLACEHOLDER Box Y-5 Case Study: California American Water Files Application for Removal of Silted-Up Dam — Dredging Not Feasible

[Any draft tables, figures, and boxes that accompany this text for the advisory committee draft are included at the end of the chapter.]

PLACEHOLDER Box Y-6 Case Study: Clear Lake — Algae in Clear Lake

[Any draft tables, figures, and boxes that accompany this text for the advisory committee draft are included at the end of the chapter.]

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Personal Communications

(Source - Rebecca Chandler, NRCS).

GLOSSARY

Geomorphic - the scientific study of landforms and the processes that shape them.

Alluvial fan - a fan-shaped deposit formed where a fast flowing stream flattens, slows, and spreads, typically at the exit of a canyon onto a flatter plain.

Anadromous fish - An **anadromous fish**, born in fresh water, spends most of its life in the sea and returns to fresh water to spawn.

1